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PRACTICAL INFORMATION FOR BEGINNERS IN IRRIGATION



FUTURE DEVELOPMENT of unimproved lands under Government and private irrigation enterprises in the United States must be accomplished largely by settlers who are not experienced in irrigation farming. Furthermore, many farmers in regions where heretofore the natural precipitation has been relied upon to grow crops are finding that irrigation is sometimes profitable under favorable conditions. This bulletin contains suggestions intended to assist beginners in mastering the details of preparing land for irrigation, laying out and building farm ditches, and so handling the water supplies as to assure the best results.

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PRACTICAL INFORMATION FOR BEGINNERS IN IRRIGATION

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SELECTING LAND FOR AN IRRIGATED FARM

THE PERSON contemplating settling in a new locality will be influenced in selecting that locality by such considerations as the climate, the crops which he prefers to grow and can grow profitably, the surface features of the land on which he proposes to settle, and the soil conditions.

CLIMATE AND CROPS

Those persons who desire a mild winter climate will naturally be attracted to the southern belt of the arid States, which includes Texas, New Mexico, Arizona, southern Nevada, and the greater part of California. Those who prefer cooler summers, coupled with short winters of frost and snow, will find such conditions in the central belt, extending from western Kansas through Colorado, Utah, western Idaho, northern Nevada, and north on the Pacific slope to eastern Oregon and Washington. Those who come from northern latitudes will do well to consider Nebraska, the Dakotas, Wyoming, eastern Idaho, and Montana. Irrigation is practiced in all these regions. The soil, climatic conditions, cost of water, and area to be irrigated will determine to a large extent the crops to be grown.

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SURFACE FEATURES

The cost of preparing land for irrigation is an important consideration in the first cost of the land. A smooth surface with a uniform slope of from 10 to 20 feet to the mile is best. It costs little to put such land in shape for irrigation and the slope favors good drainage. Buffalo or hog wallows, sand dunes or hummocks, or ravines make it difficult to reduce the land to an even grade, and cause extra labor and cost before water can be put upon it. Land having too much or too little slope is difficult to irrigate.

Land covered with hog wallows or sand dunes may require an expenditure of three times as much money before it is in shape to be irrigated, as smooth land with satisfactory slopes.

Another serious objection to land which requires much grading is that removing the surface soil from the high spots is almost sure to expose a less fertile subsoil. If the soil is shallow the high spots may be completely ruined by deep cutting.

SOIL CONDITIONS

In choosing land to be irrigated a careful examination should be made of the character and depth of the soil, its behavior when irrigated, the slope and evenness of the surface, the presence of injurious salts, and the facilities for drainage. One of the best indications of the character of the soil is the native vegetation. When sagebrush, buffalo grass, or cactus is found on a tract, it is reasonably certain that the soil is fertile, easily tilled, and well drained, although additional drainage may be necessary when the land is irrigated. The plants named are but a few in a large group which grow on good soil, easily irrigated. On the other hand, greasewood, saltwort, salt weeds, or other similar plants indicate a soil that contains some injurious salts, usually grouped under the common name of alkali, and that is often heavy and difficult to cultivate.

In arid regions most native plants obtain their food and moisture from considerable depths; the deeper the soil, the larger is the feeding ground for the roots and the greater is the capacity of the soil to store water. In the warmer parts of the West the top layer of soil protects the moist soil beneath, which furnishes both food and water to the fibrous roots. A hard, impervious stratum lying between the first and fifth foot prevents deep rooting and the storage of moisture. A hard stratum lying between the fifth and tenth foot is likewise injurious, but less so. On the other hand a porous stratum of coarse gravel underlying the surface soil may permit large quantities of irrigation water to percolate beyond the root zone. It indicates good drainage, however, and is more desirable than an impervious subsoil. The character of the subsoil may readily be determined by boring holes with a suitable soil auger to a depth of 10 feet, if necessary, and taking samples at different depths.

The rates at which different soils absorb water differ greatly. A coarse sandy soil may take up as much water in 15 minutes as a heavy clay will absorb in 100 hours or more. Easily irrigated soils may be satisfactorily moistened to a depth of 2 or 3 feet by applying water for from two to six hours. Some soils are so im-

pervious that it is difficult to wet them for more than a few inches below the surface, and others are so porous that the water soon percolates through them beyond the reach of the deepest roots. The surface of some soil bakes and cracks after each wetting, rendering cultivation difficult and checking the growth of plants. In general, sandy loams irrigate well while clay does not absorb water readily, is hard to cultivate, and bakes and cracks when drying. Usually it will be possible to observe the irrigation of fields having soil similar to that on the farm being considered. If this is not possible, a trial may be made on a small scale to determine how the soil acts under irrigation.

If land does not have good natural drainage, artificial drainage must be provided, since it is impossible to supply crops with sufficient water for their best growth without applying so much that some will seep into the subsoil. The subject of drainage is discussed briefly on page 36. For detailed information see Farmers' Bulletin 805, Drainage of Irrigated Farms.

WATER SUPPLIES AND WATER RIGHTS

The water supply for a farm may be obtained from the unappropriated waters of a natural stream, from underground sources, from a canal company which has water rights to sell, or from a Government irrigation project, but usually a particular tract can obtain water from only one source. Occasionally water can be obtained from a natural source by a single farmer, but more frequently the united effort of a number of farmers is required.

NATURAL STREAMS

Before diverting water from a stream the individual farmer or manager of an irrigation company should seek information from the proper State officials. Most Western States have laws governing the appropriation of water for irrigation. In those States the diversion and distribution of public waters are under the supervision and control of a State engineer or a State board of irrigation, from whom may be obtained information on the flow in any particular stream, the volumes which have been appropriated and used, the balance, if any, subject to appropriation, and the regulations governing the use of water. In States which have no such officers, intending settlers would do well to consult some reliable lawyer familiar with existing rights to the use of water in the neighborhood. Some local engineer also may be profitably consulted on the amount and reliability of the water supply from a particular source.

Since the flow of streams is not constant but varies from day to day and from year to year, and since in most cases there is not sufficient water to supply all needs, water rights are not as definite as land titles. The prospective purchaser of a farm in an irrigated region must find out whether the water to which his right may entitle him will be sufficient in normal years. A State permit or license is simply an authorization to use water after all earlier rights are satisfied, and the total demand of the earlier rights may be as great or greater than the entire flow of a stream except in times of flood.

LARGE CANALS

The source of water supply for new settlers is likely to be an irrigation canal built by private enterprise or by the Government. A few of the most important features of canal water rights are outlined in the following paragraphs:

Under the doctrine of appropriation, which is the governing principle of the law in most Western States, when two or more canal companies or individuals take water from the same stream, those whose rights were acquired last are the first to suffer when scarcity exists. Some canals have an abundance of water throughout the crop-growing season; others carry a full volume during the flood season and a diminished volume the remainder of the time. Some do not have an adequate supply for the last irrigation of such crops as alfalfa and potatoes, and others may have no water after the spring floods. The value of a water user's right to a portion of the volume carried by a canal will depend to a large extent upon the nature of the stream from which the supply is taken, the priority of the canal, the number of water rights sold, the amount allowed for each irrigation or for the season, and the general efficiency of the system.

Companies dispose of the water conveyed in canals on contracts with individual owners. Formerly the prevailing type of contract provided for the sale of a perpetual water right for a given tract of land, with an additional annual charge for the operation and maintenance of the canal system, but this type is no longer common.

Under some canals the purchase of a water right is not required, the total charge for water being paid annually in the form of water rental. Companies of the foregoing types are known as commercial irrigation companies. Water rights are now commonly disposed of through the sale, with the land, of rights which carry an interest in the works supplying water, so that those works become the property of the landowners when a fixed portion of the rights have been paid for. Thereafter the system is operated by a mutual irrigation company, the capital stock of which is owned by the water users. When the land to be irrigated lies in an irrigation district (a public corporation of farmers organized to provide irrigation water), the ownership of the land carries with it a right to water from the works belonging to the district. The cost of these works is levied against the land in the form of taxes, and is not included in the purchase price. The irrigation district is now a generally accepted form of organization.

Contracts vary greatly as to the quantity of water which the companies agree to furnish. Probably the most common contract promises a stream of a given size—for example, 1 cubic foot per second for each 80 acres of land—on condition that the purchaser will turn off the water when it is not needed. Other companies agree to furnish, during each season, enough water to cover the land to a given depth. Practically all such contracts provide, however, that in case of shortage of water the company shall "prorate" what water it has; that is, in case the company has not enough water to supply all it has contracted to deliver, it shall divide what it

has among all its contract holders. Few companies always have enough water to fill all contracts, and the effect of a contract having a "prorating clause" is that the purchaser will receive a share of what water the company gets rather than a stream of a given size or a fixed quantity during the season. The share he will receive depends on the number of water rights sold. This applies also to contracts with mutual companies and irrigation districts. The settler buys, instead of a water right, a share of whatever water the canal carries. In fact, under practically every form of water right not covering water taken directly from a stream, the farmer gets a share of the available supply rather than a fixed quantity. Under most contracts a short supply does not decrease the charge to the customer. Therefore it is necessary to pay as much attention to the rights owned by the company as to the form of the contract.

The value of contract water rights likewise depends on the way the canal is managed. Care and efficiency in maintenance and operation, equitable distribution of water, and sufficient resources to meet all necessary expenses are important factors in determining the value of a water right. Intending settlers should give attention to the permanency and stability of the canal system. Floods frequently destroy canal structures, and before repairs can be made crops may suffer or perish for lack of water. Also, breaks are likely to occur at the weak points in the canals, water must be turned off while they are being repaired, and the interruptions injure the owners of water rights.

Several methods are used in the delivery of water to landowners on large irrigation projects. From the viewpoint of the farmer, the delivery-on-demand method is the most satisfactory. It can be used where canals and laterals have sufficient excess capacity and the water supply is from storage or from a stream having a surplus. Under this plan the irrigator notifies the water master, usually two or three days in advance, when and for how long a period he wants a stated stream of water. Delivery is made at the time called for, or as soon thereafter as possible.

For the farmer who has a holding large enough to require the full time of one or more irrigators, or who has a very impervious soil, the continuous-flow method is satisfactory. Under this system water, if available, ordinarily is used continuously during the driest part of the season. This method requires the smallest operating force and the minimum capacity of canals and laterals. For these reasons the plan is often preferred by canal managers. For the ordinary small or medium size farm it is not satisfactory because the stream supplied is often too small for efficient irrigation and too much time is required to attend it.

In many cases a well-planned rotation system is best. Under this system a large stream is supplied to each landowner in turn. Each head or stream is large enough for efficient irrigation under the conditions prevailing, and is delivered to each farmer during a period proportioned to the area which he is irrigating. The rotation period, that is, the time between deliveries of water to the same individual, should be adjusted to the types of soils and crops being irrigated.

The United States Government has constructed a number of irrigation systems, called "projects," throughout the Western States. Many of these have now been turned over to the settlers for operation. In most cases the irrigation-district form of organization is used, and water rights and payment requirements in these districts are not much different from those prevailing in other irrigation districts. On tracts not yet fully settled, or to be served by systems still under construction, farm units are often available for settlement. Public lands in Federal irrigation projects may be obtained by meeting certain requirements in farming experience and financial backing and by paying nominal fees for filing. The cost of constructing the systems must be repaid by the settlers in 20 or 40 years. In addition, the annual operation and maintenance cost must be paid. Privately owned lands served by these systems are for sale. On the new undertakings the raw land in private ownership has been appraised and is sold at fixed prices. The cost of construction, operation, and maintenance of the irrigation systems must be met on private as on public lands. Information on location, prices, and terms on such lands can be obtained by addressing the Commissioner of the Bureau of Reclamation, Department of the Interior, Washington, D. C.

RESERVOIRS AND PUMPING PLANTS

Where the entire summer flow has been appropriated a water supply can sometimes be obtained by building a storage reservoir or by installing a pumping plant. Small enterprises of this character may be undertaken by individuals, associations, or mutual companies. A large number of small and medium size reservoirs have been built by farmers in the basins of the Cache la Poudre and Big Thompson Rivers, in northern Colorado. For methods of constructing small reservoirs, see Farmers' Bulletin 828, Farm Reservoirs. In portions of California a large part of the water supply is pumped from wells. For a discussion of pumping from wells see Farmers' Bulletin 1404, Pumping from Wells for Irrigation.

SUPPLEMENTARY IRRIGATION

In many regions where the natural rainfall is usually relied upon for crop production, more or less severe droughts occur frequently. Often a light irrigation would greatly increase crop yields and occasionally would save valuable crops or prevent serious injury to orchards.

Since the construction and operation of irrigation systems will add to the cost of crop production, caution should be exercised in extending irrigation, especially to crops yielding a low return per acre. Crops producing high values per acre, such as garden truck, fruit, and other specialties, will often return a profit on the cost of irrigation. Where surface supplies of irrigation water can be obtained cheaply, pastures and field crops may profitably be irrigated in some areas outside of the arid West. Irrigation can not be expected to pay on poor lands where lack of fertility rather than lack of moisture is the limiting factor. For this reason irrigation systems in humid areas should be confined to the better soils.

Since irrigation in humid regions is supplementary only, and not generally practiced, the prospective irrigator will meet special problems which are not common in the arid regions. Some of these problems are discussed in Farmer's Bulletin 1635, Surface Irrigation in the Eastern States, and Farmers' Bulletin 1529, Spray Irrigation in the Eastern States. In most instances the farmer in a humid area will have to develop his own water supply, often by pumping from streams, ponds, or wells. If he plans to irrigate by surface methods he will have to rely on his own resources to level the land and to construct and operate his ditches. If he is growing a high-priced crop he may find a sprinkler system most suitable, and if his soil is too shallow or too uneven for leveling or too sandy for successful surface irrigation he may be obliged to install a sprinkler system. Most of the information in the following pages applies to irrigation wherever practiced.

MEASURING WATER

The cubic foot is the basic unit of volume measurement of water, but the acre-inch and the acre-foot are more useful. An amount of water sufficient to cover an acre to a depth of 1 inch is an acre-inch. An acre-foot of water will cover an acre to a depth of 1 foot. The basic unit for measuring rate of flow is the cubic foot per second, often abbreviated to second-foot. This is equivalent to the quantity of water flowing at a velocity of 1 foot per second through a square flume 1 foot wide and 1 foot deep.

In the early days in the West the placer miners measured water by allowing it to flow through a rectangular opening in a box or flume. The height of the water surface in the box above the center of the opening varied in different districts. The flow of water was measured by the size, in square inches, of the opening required to keep the level of the water in the box at standard height. The water discharged through each square inch of the aperture was called a "miner's inch." On account of the different pressures used, the miner's inch is not the same in all States. In southern California, Idaho, Kansas, New Mexico, North Dakota, South Dakota, Nebraska, and Utah 50 miner's inches equal 1 cubic foot per second; in Arizona, Nevada, Montana, Oregon, and central California 40 miner's inches equal 1 cubic foot per second; and in Colorado 38.4 miner's inches are commonly considered equal to 1 cubic foot per second.

Pump manufacturers generally rate their equipment in terms of gallons per minute. One cubic foot per second equals approximately 450 gallons per minute.

A stream of 1 cubic foot per second (450 gallons per minute) will supply practically 1 acre-inch per hour or 2 acre-feet in 24 hours.

Of the various devices for measuring water on the farm, the weir is the simplest to install and operate and the most commonly used. Two types of these, shown in Figures 1 and 2, are known as rectangular and triangular notch weirs, respectively. Figure 3 shows a Parshall measuring flume in a lateral. This type of measuring flume requires very little drop in grade, is self-cleaning, is easily constructed, and is moderate in cost.

Further information regarding farm weirs and measuring flumes is given in Farmers Bulletin 1683, Measuring Water in Open Channels.

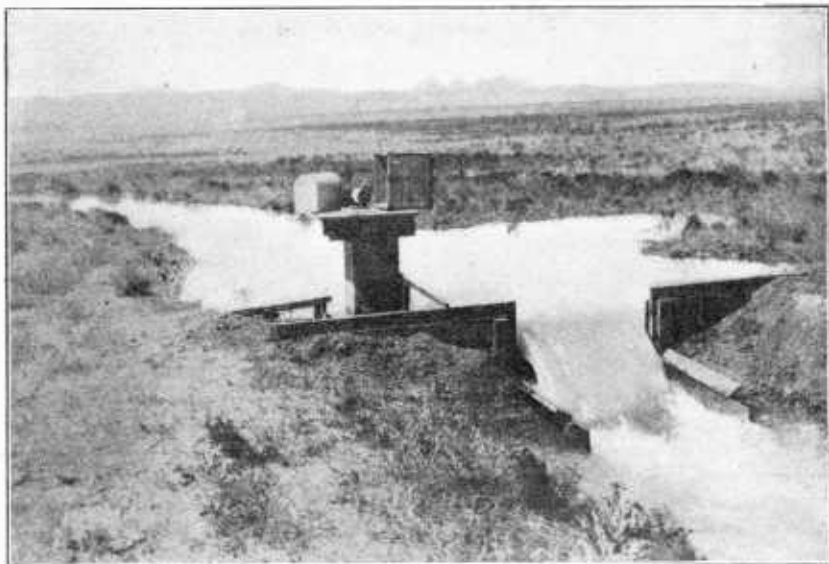


FIGURE 1.—Rectangular weir and recording device

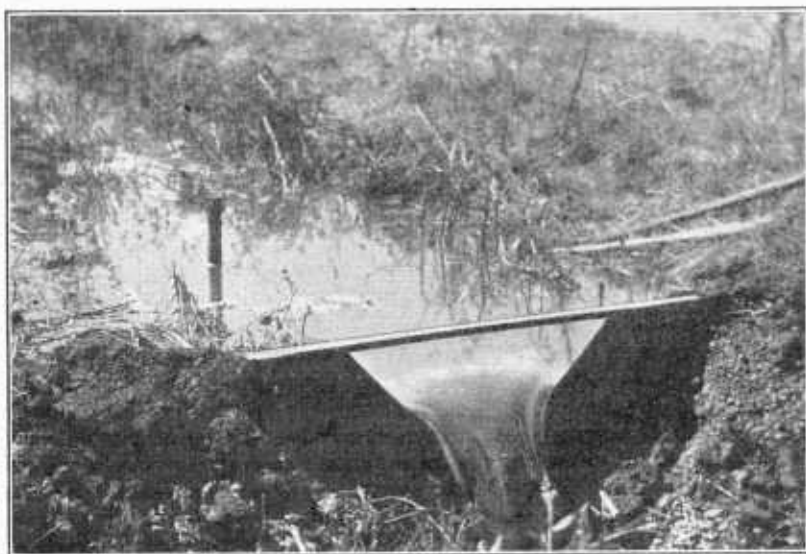


FIGURE 2.—Triangular notch weir (portable form)

CAPACITIES OF FARM DITCHES

In Table 1 the velocity and quantity of flow in each of five types of farm ditches to be described later are given for different grades.

CAPACITIES OF FLUMES

Sometimes it is necessary to carry water around rocky hillsides, down steep slopes, or across depressions. For these purposes wooden or metal flumes may be used. Tables showing the capacities of the different sizes of metal flumes at various grades are furnished by the manufacturers of such flumes. Capacities of rectangular wooden flumes are shown in Table 2. The same table may be used to estimate the capacity of concrete flumes or concrete-lined ditches. Since flumes and pipes are not easily eroded, much higher velocities may be used in them than in earth ditches.

CAPACITIES OF PIPES

Where water is pumped it often must be forced through pipe lines of considerable length. The pump must exert sufficient pressure to lift the water from its original level to the elevation of the outlet



FIGURE 3.—Parshall measuring flume

and to overcome friction in the pipe. Table 3 gives the capacity of four sizes of pipe when flowing full on various grades. It makes no difference whether the grade is an actual fall or slope or is a hydraulic or pressure gradient from a pump. The capacities given in Table 3 are for concrete pipe; wood or iron pipe will carry somewhat more. Most pump and pipe catalogues contain more extensive tables of pipe capacities.

CONSTRUCTING FARM DITCHES

Whatever the source of supply, ditches are necessary to convey the water to all parts of the farm. The larger ditches and canals need not be considered in this connection, for they usually are built by contractors under competent engineers, but most farm ditches are

located and built by farmers without assistance from engineers or surveyors.

The ditch capacity needed depends chiefly on the methods of delivering and applying the water. It depends, also, but to a less extent, on the size of the farm, the nature of the soil, and the crops raised. In this discussion capacities of ditches are generally stated in cubic feet per second.

TABLE 1.—*Mean velocity and discharge in ditches with different grades*

FARM DITCH NO. 1 (FIG. 4)						
Grade			Mean velocity in feet per second	Discharge		
Inches per rod	Feet per 100 feet	Feet per mile		Cubic feet per second	Miner's inches	
					40 equal 1 sec.-ft.	50 equal 1 sec.-ft.
½	0.25	13.33	1.0	0.7	25	35
1	.51	26.67	1.4	1.0	40	50
1½	.76	40.00	1.8	1.2	45	60
2	1.01	53.33	2.1	1.4	55	70
2½	1.26	66.67	2.3	1.5	60	75
3½	1.77	93.33	2.7	1.8	70	90

FARM DITCH NO. 2 (FIG. 5)						
¼	0.13	6.67	0.9	0.9	35	45
½	.25	13.33	1.2	1.2	50	60
1	.51	26.67	1.8	1.8	70	90
1½	.76	40.00	2.2	2.2	90	110
2	1.01	53.33	2.5	2.5	100	130
2½	1.26	66.67	2.8	2.8	110	140

FARM DITCH NO. 3 (FIG. 6)						
⅛	0.06	3.33	0.8	1.9	75	95
¼	.13	6.67	1.2	2.8	110	140
½	.25	13.33	1.7	3.9	160	190
¾	.38	20.00	2.1	5.0	200	250
1	.51	26.67	2.4	5.5	220	280
1¼	.63	33.33	2.7	6.2	250	310

FARM DITCH NO. 4 (FIGS. 8 AND 9)						
⅛	0.03	1.67	0.7	3.7	150	180
¼	.06	3.33	1.1	5.3	210	260
½	.13	6.67	1.6	7.9	310	390
¾	.19	10.00	1.9	9.5	380	480
1	.25	13.33	2.2	11	440	550
1¼	.38	20.00	2.7	14	540	680

FARM DITCH NO. 5. (FIGS. 10 AND 11)						
⅛	0.03	1.67	1.0	11	460	570
¼	.06	3.33	1.4	16	650	810
½	.09	5.00	1.8	20	800	1,000
¾	.13	6.67	2.1	24	960	1,200
1	.19	10.00	2.6	29	1,200	1,500
1¼	.22	11.67	2.8	31	1,300	1,600

If water is obtained from a canal the capacity of the farm ditches will necessarily be based on the size of the stream from the canal.

If the farm has a separate water supply the size of the farm ditch will depend upon the water requirements of the farm.

TABLE 2.—Mean velocity and discharge for rectangular wooden flumes with different grades¹

FLUME NO. 1—6 INCHES WIDE, 6 INCHES DEEP						
Grade			Mean velocity in feet per second	Discharge		
Inches per rod	Feet per 100 feet	Feet per mile		Cubic feet per second	Miner's inches	
					40 equal 1 sec.-ft.	50 equal 1 sec.-ft.
1	0.51	26.67	2.0	0.25	10	12
2	1.01	53.33	2.8	.35	14	18
3	1.52	80.00	3.5	.43	17	22
4	2.02	106.67	4.0	.50	20	25
8	4.04	213.33	5.7	.71	28	35
FLUME NO. 2—8 INCHES WIDE, 8 INCHES DEEP						
1	0.51	26.67	2.7	0.8	30	40
2	1.01	53.33	3.8	1.1	45	55
3	1.52	80.00	4.7	1.3	50	65
4	2.02	106.67	5.4	1.5	60	75
8	4.04	213.33	7.7	2.1	85	110
FLUME NO. 3—12 INCHES WIDE, 12 INCHES DEEP						
½	0.25	13.33	2.7	2.1	82	100
1	.51	26.67	3.9	2.9	120	150
2	1.01	80.00	5.5	4.2	170	210
3	1.52	106.67	6.8	5.1	210	250
4	2.02	213.33	7.8	5.9	240	290
FLUME NO. 4—18 INCHES WIDE, 12 INCHES DEEP						
½	0.25	13.33	3.2	3.6	140	180
1	.51	26.67	4.6	5.2	210	260
2	1.01	80.00	6.5	7.3	290	370
3	1.52	106.67	8.0	9.0	360	450
4	2.02	213.33	9.2	10.0	420	520
FLUME NO. 5—24 INCHES WIDE, 18 INCHES DEEP						
¼	0.13	6.67	3.1	7.7	310	380
½	.25	13.33	4.3	11.0	430	530
1	.51	26.67	6.1	15.0	610	760
2	1.01	80.00	8.6	22.0	860	1,100
3	1.52	106.67	11.0	26.0	1,100	1,300

¹ All capacities are based on water surface 3 inches below top of flume.

For irrigating pastures or field crops on most soils a stream of at least 1 cubic foot per second should be supplied. If the soil is very sandy a larger stream is needed. Where alfalfa, meadows, or pastures are irrigated by border, check, or flooding methods, streams as large as 8 or 10 cubic feet per second are used. An individual water supply for a farm on which field crops are grown by surface irrigation should provide about 1 cubic foot per second if the farm contains 60 acres or less, 2 cubic feet per second for a farm of 120 to

160 acres and 1 cubic foot per second additional for each 80 acres more than 160. If row crops only are irrigated, or if a sprinkler system is used, smaller streams may be sufficient. These quantities are given only as suggestions. Under favorable conditions of soil and climate and with careful management, much smaller supplies can be used successfully. On the other hand much larger streams are used where conditions are less favorable.

FORMS

The form of cross section of the ditch depends largely on the implements used in making it. Figures 4 and 5 represent the cross sections of two ditches made with ditch plows attached to sulky frames. The ditches are cleaned out by hand after the use of the plows. The ditch in Figure 4 was made with a 14-inch lister or double moldboard plow and will carry from one-half to 2 cubic feet per second, depending on the grade. The ditch in Figure 5 was made with a 16-inch lister and will carry 1 to 3 cubic feet per second. The ditch shown in Figure 6 is somewhat larger, and will carry 2 to 6 cubic feet per second. It may be made by first plowing a strip where the ditch is to be and then removing the loose soil with a scraper or V-shaped crowder. (Fig. 7.)

TABLE 3.—*Mean velocity and discharge of concrete pipe flowing full¹*

PIPE 6 INCHES IN DIAMETER						
Grade			Mean velocity in feet per second	Discharge		
Inches per rod	Feet per 100 feet	Feet per mile		Cubic feet per second	Miner's inches	
					40 equal 1 sec.-ft.	50 equal 1 sec.-ft.
$\frac{3}{16}$	0.11	5.8	1.0	0.2	8	10
$\frac{1}{2}$	.46	24.0	2.0	.4	16	20
$\frac{2}{16}$	1.04	55.0	3.1	.6	24	30
$\frac{5}{16}$	2.88	152.0	5.1	1.0	40	50
$1\frac{1}{16}$	5.60	296.0	7.1	1.4	56	70

PIPE 8 INCHES IN DIAMETER						
$\frac{1}{4}$	0.06	3.2	0.9	0.3	12	15
$\frac{3}{8}$	.32	17.0	2.0	.7	28	35
$1\frac{1}{4}$	.64	34.0	2.9	1.0	40	50
5	2.54	134.0	5.7	2.0	80	100
$11\frac{3}{8}$	5.73	303.0	8.6	3.0	120	150

PIPE 12 INCHES IN DIAMETER						
$\frac{1}{4}$	0.07	3.7	1.1	0.6	24	30
$\frac{3}{8}$	.20	11.0	1.8	1.0	40	50
$1\frac{1}{4}$	.80	42.0	3.7	2.0	80	100
$6\frac{1}{4}$	3.15	166.0	7.3	4.0	160	200

PIPE 18 INCHES IN DIAMETER						
$\frac{3}{16}$	0.22	12.0	2.8	5.0	200	250
$\frac{1}{2}$	.44	23.0	4.0	7.0	280	350
$1\frac{1}{2}$	.90	48.0	5.7	10.0	400	500
4	2.03	107.0	8.5	15.0	600	750

¹ Adapted from Table 6, Dept. Bul. 852, U. S. Dept. of Agri.

Farm ditch No. 4, which has a capacity of 4 to 14 cubic feet per second, according to the grade, may be trapezoidal as shown in Figure 8 or curved as shown in Figure 9. The trapezoidal form is



FIGURE 4.—Farm ditch No. 1



FIGURE 5.—Farm ditch No. 2



FIGURE 6.—Farm ditch No. 3



FIGURE 7.—Finishing an irrigation lateral with a V scraper



FIGURE 8.—Farm ditch No. 4 with trapezoidal cross section



FIGURE 9.—Farm ditch No. 4 with curved cross section

made with one of many kinds of graders which excavate the ditch and deposit the earth at a little distance from the edge. The curved section is made with plow and scraper or with a plow and one of

many devices, homemade and manufactured, for removing loose dirt from ditches. Figures 10 and 11 show two forms of a ditch that will carry 11 to 31 cubic feet per second, depending on the grade. Associations of landowners often build ditches of this size to serve a number of farms. The manner of building it is similar to that of building the ditches shown in Figures 8 and 9.

GRADES

The quantity of water which a ditch will carry depends on its fall or grade as well as on its size. When a choice of grade is possible, the chief points to consider are the volume of water to be carried and the nature of the soil. The smaller the volume, the greater the grade required to produce a given velocity. In a small ditch (fig. 4) carrying 1 cubic foot per second, a grade of 2 inches to the rod would produce a velocity of 2 feet per second, while in a larger

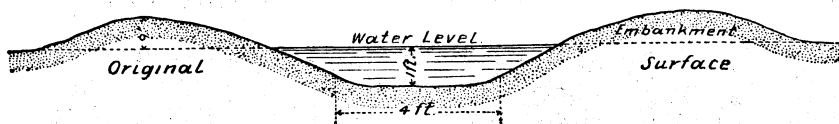


FIGURE 10.—Farm ditch No. 5 with curved cross section

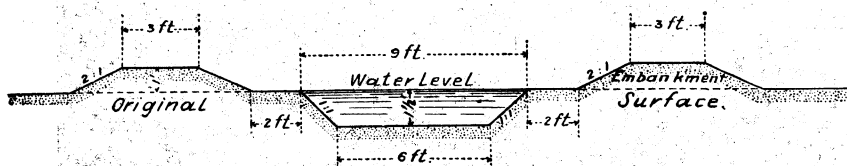


FIGURE 11.—Farm ditch No. 5 with trapezoidal cross section

ditch, carrying 20 cubic feet per second, the grade required to give the same velocity is only one-fourth inch to the rod. In fine sand or sediment a flat grade is required in order to prevent scouring. A mean velocity of 1 foot per second may be used in such material. In hard gravel or hard clay, or in a mixture of these, a velocity of 3 feet per second can be used without eroding the bottom. In ordinary materials, ranging from sandy or gravelly loams to clay loams, a mean velocity of 2 to $2\frac{1}{2}$ feet per second may safely be permitted. The grade of a ditch can not exceed that of the land. On rolling land or where the slope is steep, a suitable grade for ditches usually can be found by running them across rather than directly down the slopes. When excessive grades can not be avoided otherwise, "drops" may be constructed. These structures permit the water to fall vertically without eroding the ditch. The grade of the ditch between drops may then be made as little as desired. Check boards are convenient devices to divert water into laterals, and at a slight additional expense they may be combined with permanent drops.

LOCATIONS

It is a mistake to build ditches for the lower part of a farm and later, when it is desired to irrigate the remainder, be obliged to build a second series of ditches for the higher land. Sufficient water to

irrigate the entire area should first be conveyed from the canal or other source of supply to the highest point to be reached, and distributed thence to the various subdivisions. Permanent ditches should, if possible, be located along field or fence boundaries, in order not to obstruct the passage of teams and implements. When the grade is too steep to permit this, a curved location through fields should be chosen. Such curved supply ditches can be so laid out as to add greatly to the beauty of an irrigated farm. They become the margins of fields, and lanes are located, fences built, and fruit or shade trees planted beside them. When conditions permit, it is usually better for farm operations to locate supply ditches around the boundaries of square or rectangular tracts.

LAYING OUT DITCHES

In laying out supply ditches, an engineer's level and rod are the most convenient instruments. Architect's and farm levels, less expensive forms of the same instrument, are satisfactory for laying out small ditches. The distances may be approximately measured by pacing. When better levels are not available, an ordinary carpenter's spirit level attached to a portable wooden frame is a useful

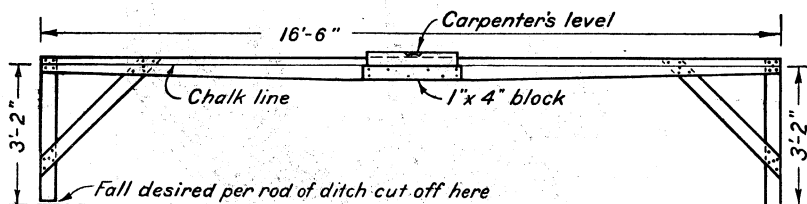


FIGURE 12.—Homemade level. The chalk line is used merely to obtain correct lengths of leg and a true setting for the carpenter's level

substitute. A sketch is shown in Figure 12. When the device is placed on a level surface, the bubble should come to the center of its run. Then one leg of the frame is shortened by the distance which the ditch is to fall in 1 rod of its length. (Table 1.) The operator places the bottom of the shorter leg on a level with the surface of the water in the canal or other source of supply, and the other end of the device is swung around until, with the longer leg resting on the ground, the bubble comes to rest in the center of its run. A helper marks the location of the longer leg with a small stake, the level is carried forward, and the short leg is placed on the spot vacated by the longer. Again the device is leveled by moving the longer leg up and down the slope of the ground until the bubble is in the center of its run, a second stake is driven at the point occupied by the longer leg, and the device is moved forward again. This operation is repeated until the entire line of the ditch is laid out, when a furrow, connecting all the short stakes, is run.

CROSSING DEPRESSIONS

Many farms are cut up by ravines or depressions, and supply ditches must be extended across these. Usually this is done in one of three ways: (1) By levees on each side of the ditch, if the depres-

sion is only a few feet deep; (2) by wooden or metal flumes built on grade; or (3) by a pipe laid in the form of an inverted siphon. The earth levee, if very low, is the cheapest, but it is subject to leaks and washouts for the first few years. The wooden flume answers the purpose fairly well, but is subject to early decay. The concrete pipe laid beneath the ground surface, although higher in first cost, often is really the cheapest in the end. When a short length of pipe or flume is used to carry a ditch over a depression it should have about the same dimensions as those of the ditch.

Where laterals or ditches are crossed by farm roads or highways, suitable structures must be provided. Figure 13 shows a small bridge over a lateral. Concrete or corrugated pipe culverts with suitable headwalls may be installed across smaller ditches. The

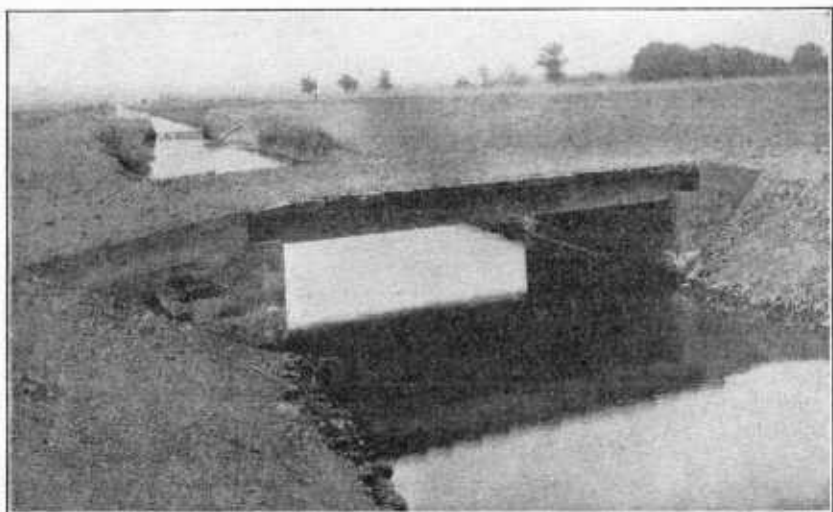


FIGURE 13.—Farm wagon bridge across small lateral

bottom of the inside of the pipe should be set at the same elevation as the bed of the ditch or a little below, and a pipe large enough in diameter to care for the full capacity of the ditch should be used. Sufficient earth should be graded over the pipe to form an adequate cushion to absorb impact and to keep the tires of vehicles from coming into direct contact with the surface of the pipe.

CONTROLLING WEEDS ALONG DITCH BANKS

On most irrigated farms the margins of supply ditches are breeding grounds for weeds. Weed seeds fall into the water and are widely scattered by the stream. The banks of ditches should be graded and smoothed so that the weeds which grow along them can readily be cut and burned. A fast-growing forage crop like alfalfa also tends to keep down the weeds and may be sown along the banks for this purpose. The right of way may be fenced and sheep pastured on it.

PREPARING LAND FOR IRRIGATION

Land should be prepared for irrigation after the supply ditches are built. While this rule is frequently disregarded, it will be found better to grade land in conformity to permanent ditches already constructed than to locate and excavate ditches to suit land that has already been graded and leveled. Field ditches, however, are located after the land is leveled.

The beginner in irrigation seldom appreciates the importance of preparing the surfaces of fields so that they may be watered cheaply, easily, and uniformly. As a rule, crop yields are good or bad according to whether proper amounts of water are applied at the right times. When the ground is left so rough and uneven that water can not be applied evenly, the effect is shown in the reduced yield. Preparation of the land is a capital investment, and if it is done thoroughly during the first or second year it will require little expense afterwards. The difference in cost between a smooth, well-graded field and one that is poorly graded and rough may not exceed \$8 per acre, yet this sum is often lost in one season through diminished yields caused by imperfect watering, the result of a rough, uneven surface. Thorough preparation of the surface is especially important with crops like alfalfa and orchards that will occupy the land for several years.

USING A TOPOGRAPHIC MAP

It is difficult to plan a proper system of irrigation for a farm without the aid of preliminary surveys. In addition to the boundaries of the farm, the configuration of the surface should be determined by a survey locating contour lines—lines connecting points of equal elevation—from 6 to 12 inches apart in vertical elevation. The character of the soil and subsoil should also be determined by boring or digging pits. The data thus obtained should be shown on a topographic map of the farm. The services of an engineer usually are necessary in making such a survey and preparing a map.

There should be, at the outset, a general plan of irrigation for the entire farm, even though only a small part may be reclaimed during the first few years of occupation. Too often the importance of this is not realized at first, the result being a wrong start which is extremely difficult to correct in later years. The location of farm laterals, the shapes and sizes of fields, the method of applying water, and the length and direction of furrows or the sizes and shapes of borders and checks can all be laid out on the map.

REMOVING NATIVE VEGETATION

Tracts which produce native grasses, low cacti, rabbit brush, and the smaller forms of brush can be plowed readily. Such land should be plowed deep, the larger growth afterwards removed, and the surface thoroughly harrowed, graded, and smoothed. In plowing for the first time, 2 acres is a fair day's work for a man and three horses, and the cost of removing the larger plants seldom exceeds 50 cents an acre. Tracts which produce tall, coarse sagebrush 3 to 5 feet high, in clumps from 4 to 8 feet apart, are more difficult to put in shape for irrigation. A serviceable homemade device for re-

moving sagebrush, can be made of a railroad rail as shown in Figure 14.

Junipers, pines, or other trees of considerable size may have to be removed. The general practice is first to cut all trees large enough for wood or saw timber. The smaller trees are then slashed and, when dry, burned with the tops and waste timber of the larger trees. Small pine stumps rot quickly, and within a year or two after being cut those 4 to 6 inches in diameter may often be removed by the direct pull of a good team. One of the many types of stump pullers may be employed to remove larger stumps. Dynamite and stumping powder are used to split or blow out those too big to be handled readily by the pullers.

The cost of removing trees and stumps varies widely according to the kind of trees and the number to the acre. The cost of clearing

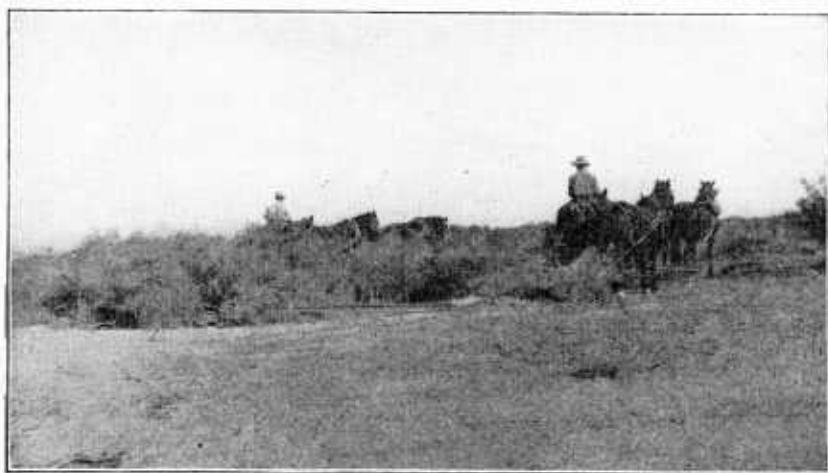


FIGURE 14.—Clearing sagebrush with railroad rail

several thousand acres of pine land in the vicinity of Spokane, Wash., ranged from \$40 to \$75 per acre. Mesquite, which is found from southwestern Texas to southeastern California, varies from a straggling, spiny shrub to a widely branched tree 50 feet high and 3 feet in diameter. Mexican labor is usually employed to grub out mesquite at a cost ranging from \$7 to \$40 per acre depending on the size and density of the shrubs. For more detailed information regarding stump removal, see Farmers' Bulletin 1526, *Clearing Land of Brush and Stumps*.

SURFACE GRADING

When land is covered with a heavy growth of sagebrush or when it is uneven, consisting of sand hummocks or heights and hollows, it is best not to attempt to complete the preparation of the surface the first season. The ground may be prepared roughly and seeded to grain or planted to potatoes. Later in the season it is irrigated as well as the nature of the surface will permit, and afterwards when the crop is removed it is thoroughly prepared for a permanent crop, like alfalfa. The roots of native grasses are then dead and the brush

roots interfere much less with scrapers, graders, and other farm implements.

In the thorough preparation of a field for irrigation it is first plowed deeply and then graded with one of the implements commonly used for that purpose. Of these, the steel-shod float shown in Figure 15 is one of the most serviceable. This float is 6 feet wide and 32 feet long and has nine cross members. If horses are used, a float somewhat shorter, having three to five cross members, may be used. Various types of grading implements, referred to in greater detail later, also may be used to advantage.

PREPARING LAND FOR STANDARD METHODS OF IRRIGATION

Many methods of applying water are used in western North America, but the few herein described may be regarded as representative of all, the remainder being modifications of those discussed. A general knowledge of these is useful to the settler in that it enables him to compare their relative cost and efficiency, and assists him in deciding which is best suited to his problem. The construction of the

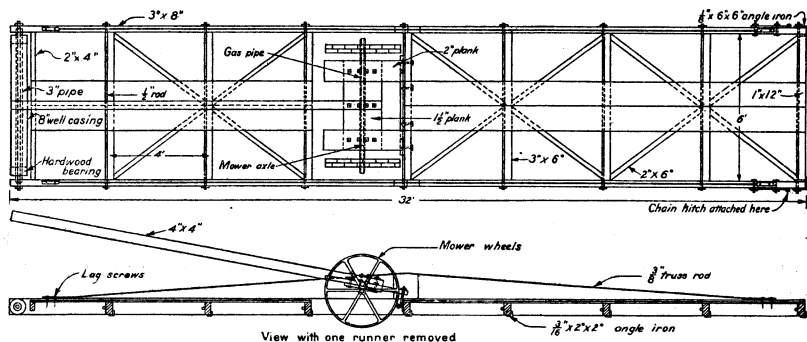


FIGURE 15.—Land leveler or float. Harney Branch Experiment Station, Oreg.

supply ditches and the preparation of the surface should conform at the start to the method adopted.

FLOODING FROM FIELD LATERALS

While flooding from field laterals is laborious and not the most effective method of irrigation, it is the most common. Probably 40 per cent of all the land irrigated in the West is still watered in this way. The cheapness of this method commends it to settlers of limited means. Besides, it is fairly well adapted to conditions such as are found in most of the Mountain States where the land is often rolling and the most fertile soil is shallow. Its use may be recommended when the land to be irrigated is reasonably cheap, when the water is delivered in continuous streams or in small heads for given periods of time, when the members of the family can do the irrigating, and when grain and forage crops are to be raised.

When a field has been leveled and graded, small ditches (figs. 4 to 6) called field laterals are run through it. This work may be done either before or after seeding. On fields intended for alfalfa

or meadows the laterals are made larger and with more care. (Figs. 8 to 11.) Usually they are located on a grade of from one-half to three-fourths of an inch to the rod, and are spaced about 75 feet apart in grainfields and about 90 feet apart in alfalfa fields. Sometimes the laterals extend down the steepest slope from the supply ditch. Figures 16 and 17 indicate these two methods of locating

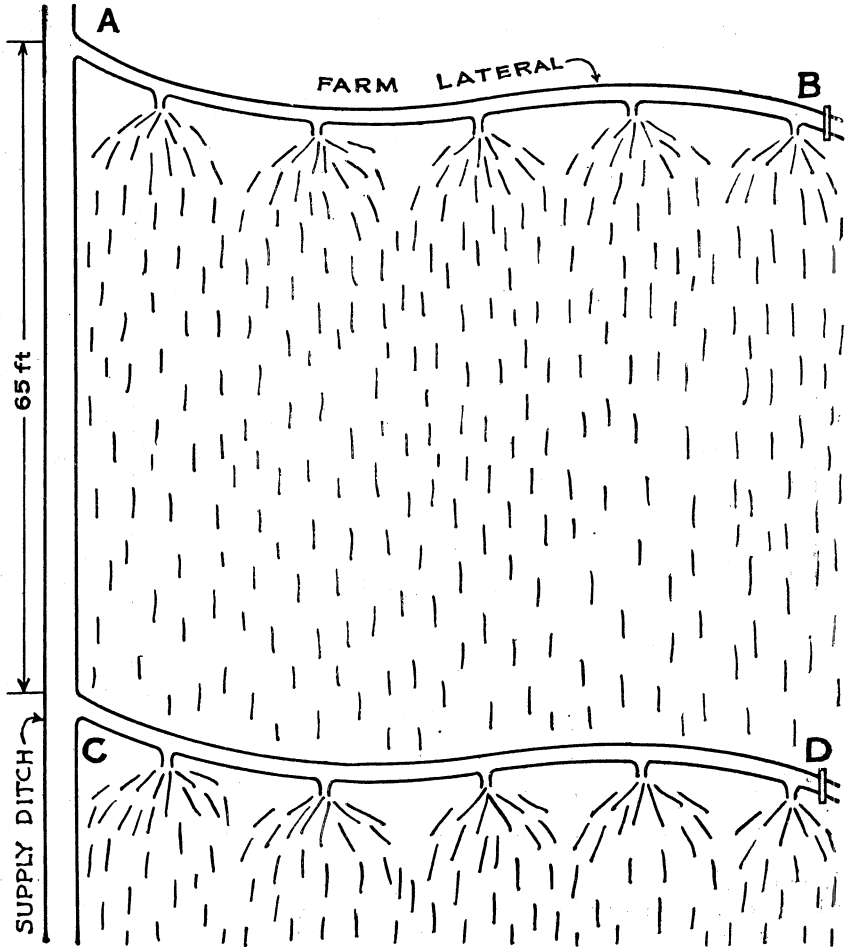


FIGURE 16.—Flooding from field laterals

laterals. Small laterals may be made with a common walking plow, but a lister or double moldboard plow attached to a sulky frame is to be preferred for medium-sized ditches. The larger laterals, designed to carry 4 or 5 cubic feet per second, may be constructed easily with an implement made by riveting together two steel beam plows, one with a right-hand and the other with a left-hand share. A steel ditcher used for this purpose is shown in Figure 18.

In irrigating by flooding, one irrigator can attend to two streams of from 1 to 3 second-feet each unless the land is too steep or is

poorly prepared. Temporary dams are placed in the laterals which cause the water to flow over the banks of the ditches or through specially prepared cuts. The distance of the dams from each other will depend on the size of the stream used and the slope on which the laterals are built. After a few trials it is comparatively easy to judge how far apart they must be in order to get the best results.

Temporary dams may be made of canvas, of metal, or simply of earth. A canvas dam (fig. 19) is easily made from a piece of heavy duck about 2 feet longer than the width of the ditch at the water

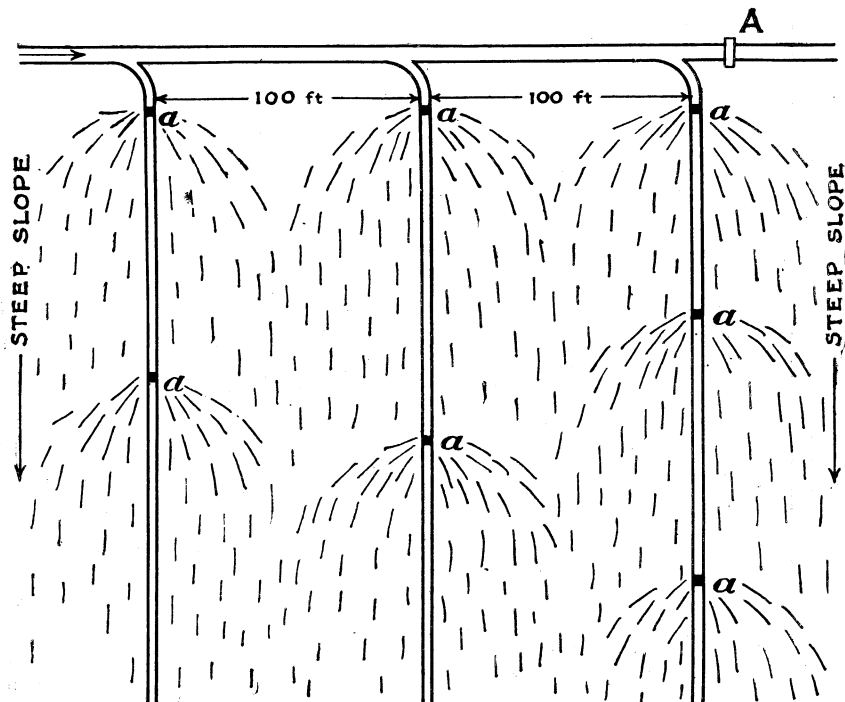


FIGURE 17.—Flooding from ditches running down steepest slope

surface and about 3 feet wider than the depth of water. One side of the canvas is nailed to a pole or scantling some 2 feet longer than the canvas. To use the dam, the pole is laid across the ditch with the canvas spread out upstream. A few shovelfuls of soil placed on the upstream edge of the canvas hold it down to the bottom of the ditch. Often, especially in furrow irrigation, part of the water is allowed to pass on down the ditch to the next dam. Its passage is provided for by cutting a small V-shaped notch in the canvas or by using a crooked pole which sags in the middle enough to let the required amount of water pass. Temporary metal dams, sometimes called tappoons, are simply sheets of 16 to 20 gauge sheet metal, cut to fit the cross section of the ditch roughly. They are reinforced on the upper edge for stiffness and for convenience in handling. Metal dams are sometimes made in two sections, hinged in the center so

as to make them adjustable to the size of the ditch. Openings may be cut in metal dams, also, to allow part of the water to pass.

Sometimes small furrows or dikes must be built to guide the water in order that all the land between the laterals may be wetted. After the whole space between two laterals opposite the first dam has been thoroughly moistened, this dam is removed, the water allowed to flow down to the next temporary dam, and the process is repeated.

FURROW IRRIGATION

Nearly all crops planted in rows and cultivated are irrigated by means of furrows between the rows. (See front cover illustration.)

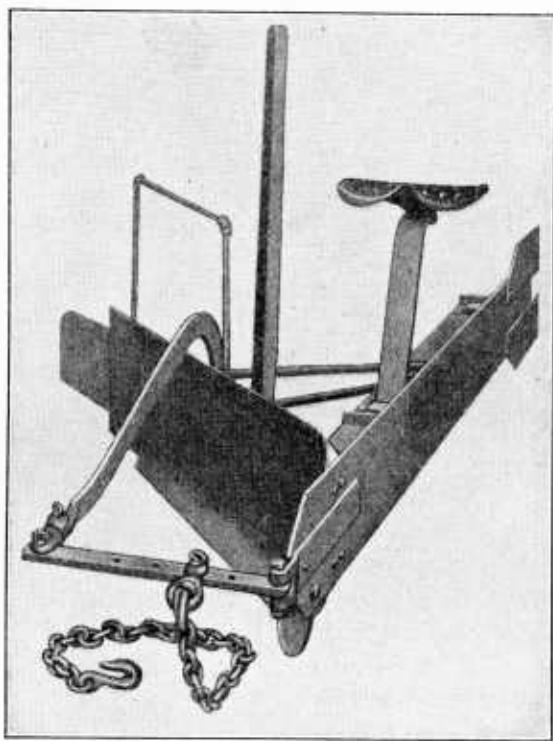


FIGURE 18.—Steel V ditcher

This applies to such crops as potatoes, sugar beets, corn, cotton, melons, vegetables, and fruit. Some soils bake and crust badly after the surface has been wet; others are so steep that newly seeded crops can not be irrigated by flooding. In some cases only small streams of water are available for irrigation. Under all of these conditions small grains, hay, and pastures are often irrigated by the use of small furrows 18 to 48 inches apart. This is the furrow or corrugation method of irrigation. For more detailed information, see Farmers' Bulletin 1348, *The Corrugation Method of Irrigation*. In preparation for using this method the ground is first plowed, leveled, and graded in much the same way as that described for flooding from field laterals. The field is then divided so that each part can be

watered readily from a ditch running approximately at right angles to the furrows, called the "head ditch." The distance between any two adjacent head ditches depends chiefly on the soil. In porous, sandy soils, furrows should not be more than 300 feet long. In soils which absorb water less freely, they may be from 400 to 1,000 feet long. The head ditches are fed from the main supply ditch of the farm, and usually are made after the field is partially leveled and graded.

The chief difficulty in furrow irrigation is to divide the water in the head ditch fairly equally among a large number of furrows. The irrigator may wish to turn water into 50 furrows at the same time, and unless he uses some device other than a shovelful of dirt taken out of the ditch bank the distribution will not be uniform. One of the best devices yet used for this purpose is a short pipe or spout, which may be made of wood. For streams of less than 1 miner's inch, two pine laths cut in two and the four pieces nailed together in the form of a pipe serve very well. For streams requiring

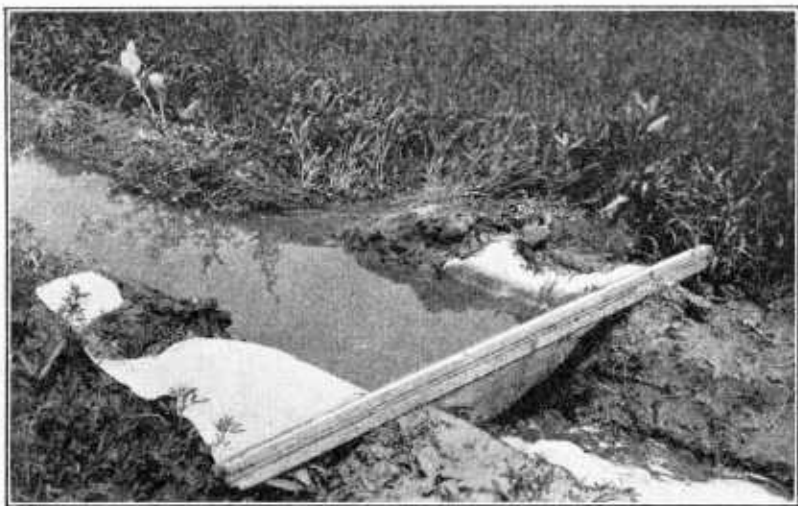


FIGURE 19.—Canvas dam in use in a field lateral

from 1 to 6 miner's inches half-inch boards of the required width are used in place of the laths. Figures 20 and 21 show these two forms of wooden spouts. One of these pipes is inserted in the lower bank of the head ditch opposite each furrow. When this system is used, the head ditch should be divided into a series of level sections by checks and drops, rather than have a uniform slope. In each section the pipes should be set at the same elevation, 2 or 3 inches below the water level.

Sometimes a small temporary head ditch is built just below and parallel to the main supply ditch. The water is distributed to the furrows from the head ditch. Where water is scarce and valuable flumes and pipes of various kinds are used to convey and distribute the water to furrows. A sketch of a distributing flume built of wood is given in Figure 22 and a sketch of a concrete flume in Figure 23.

A wooden trough and a surface pipe for distributing water to furrows are shown in Figures 24 and 25.

Head flumes of either wood or concrete, being placed on the surface of the ground, interfere greatly with the free passage of teams and implements in cultivating, irrigating, and harvesting the crop, and dead leaves clog the small openings in the flumes. Weeds grow in the space on each side of the flumes and the seeds are spread by the water in the open channel. These and other objections to flumes

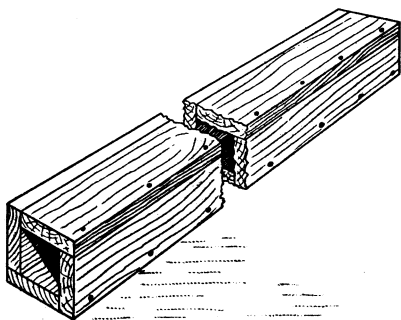


FIGURE 20.—Lath pipe for ditch banks

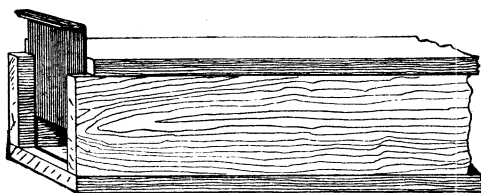


FIGURE 21.—Pipe for ditch bank made from half-inch boards

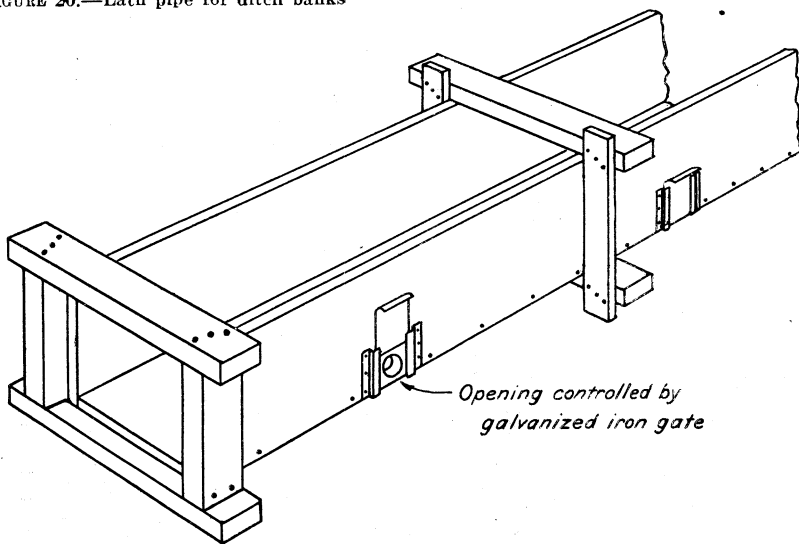


FIGURE 22.—Wooden flume

have induced many orchardists to convey and distribute the water in underground pipes. For more detailed information on pipes and distributors see Farmers' Bulletin 1518, Orchard Irrigation.

The tracts between the ditches should be well graded so as to allow a small stream to flow steadily down each furrow. Common farm implements may be used for this purpose. The railroad rail previously mentioned (p. 18), and the buck scraper shown in Figure 26, often may be used to advantage.

The size of the stream supplied to each furrow will depend on the length of the furrow, the nature of the soil, and the slope of the

ground. The longer furrows, the coarser soils, and the flatter slopes require larger streams. With very sandy soils, as large a stream as can be used without washing is best, and the water should be shut off as soon as it reaches the ends of the furrows. With very tight soils, on the other hand, very small streams should be used and they should run for a long time, perhaps for several days in extreme cases, in each set of furrows. With some intermediate soils it is a good plan to turn a rather large stream into each furrow until the water has reached nearly to the lower end and then reduce the size of the stream until just a trickle of water reaches the end of the furrow.

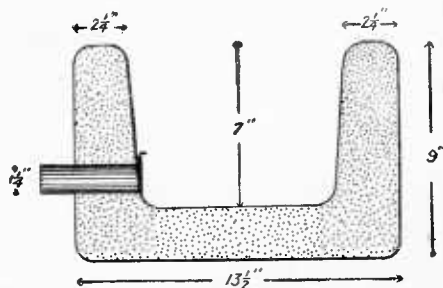


FIGURE 23.—Cross section of 8-inch concrete flume

CHECK IRRIGATION

The check method is confined mainly to the irrigation of alfalfa. It consists in dividing up the field into checks or basins each com-

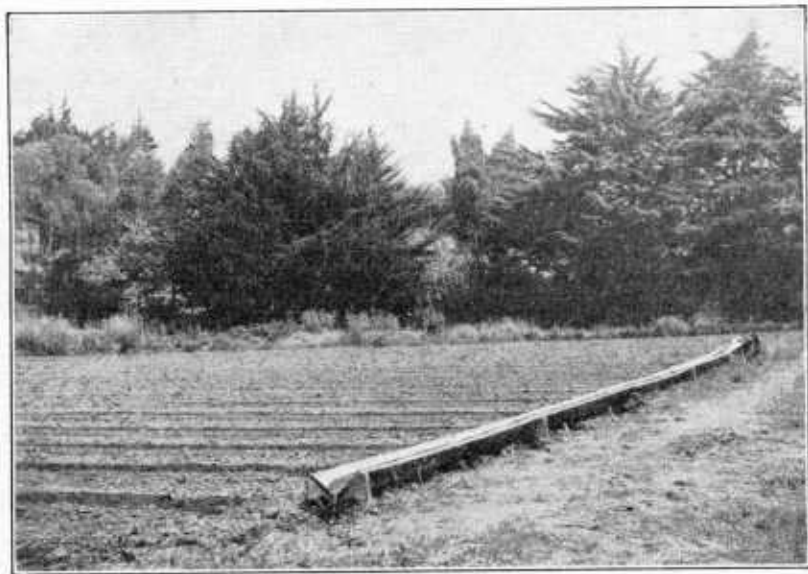


FIGURE 24.—Distributing water through a wooden trough

prising, as a rule, from one-half acre to $1\frac{1}{2}$ acres. These checks may be rectangular, or their upper and lower boundaries may follow contour lines. Around the margin of each check a low embankment or levee is formed to retain the water until it has been absorbed by the soil.

The field to be checked is first laid out in contour lines—the difference in level between any two lines being 3 inches or more, de-

pending on the slope. On land which slopes about 8 feet to the mile contour lines would be 3 inches apart vertically and about 160 feet apart horizontally. On steeper slopes the horizontal distance is increased but for convenience in farming operations it is advisable to increase the vertical distance as well. Land which slopes 50 feet or more to the mile is not suited to check irrigation. The contours may be located by the use of an engineer's level and rod, or by the

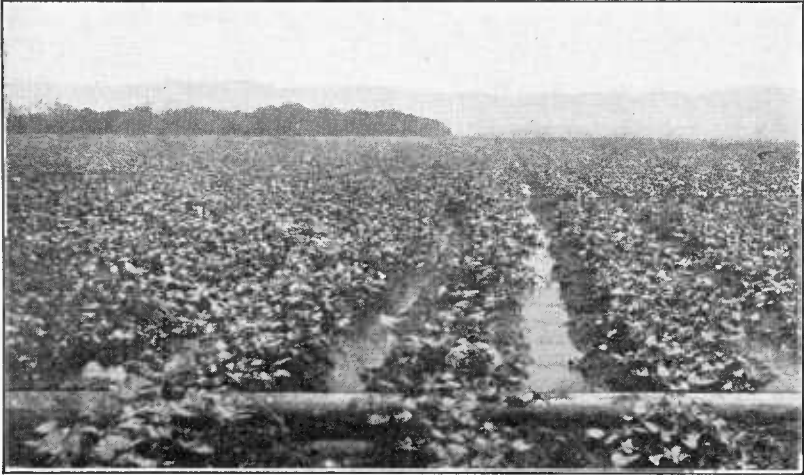


FIGURE 25.—Distributing water through a galvanized pipe

homemade level already described. (P. 19.) When the contour lines have been run, levees are built and the intervening spaces are subdivided by cross levees into areas containing on an average about three-fourths of an acre. Provision is also made at this time for field ditches to convey water to each check. After temporary stakes are set to mark the corners of the checks, a plow furrow is run around the margin of each so as to mark it more permanently.

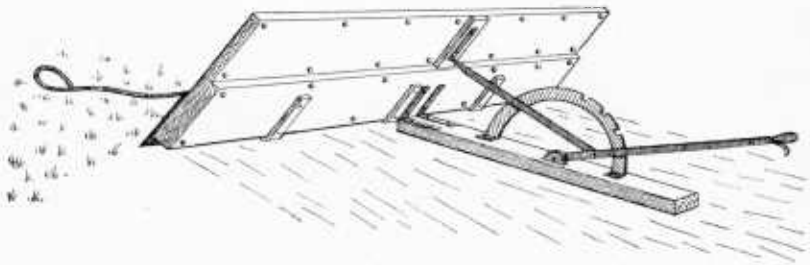


FIGURE 26.—Buck scraper

This being done, portions of the field may be checked when time permits. Many farmers prefer rectangular to contour checks. In laying these out, contour lines are run and the rectangular checks are fitted into the spaces in such a way as to require the moving of the least possible volume of earth. Such checks cost more at first, but are more convenient for farming operations.

In building the levees around checks, a scraper drawn by a tractor or by two or three horses or mules, is generally used. All knolls and hummocks within the check are first scraped down and the earth placed in the levee. If more dirt is needed the high corner or end of each check is removed, leaving the floor fairly level or with a slight grade away from the check box where the water is admitted.

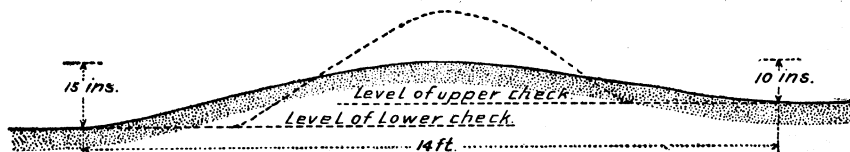


FIGURE 27.—Low, broad check levee

Levees are also made by plowing twice across and back along the line and crowding the earth into the levees with a V crowder (fig. 7) or with a leveler or grader. The field is then plowed, harrowed, and seeded in the usual way. Levees when first built are too high and steep, but with subsequent plowing, harrowing, and settling they should become similar to that shown in Figure 27 about the time

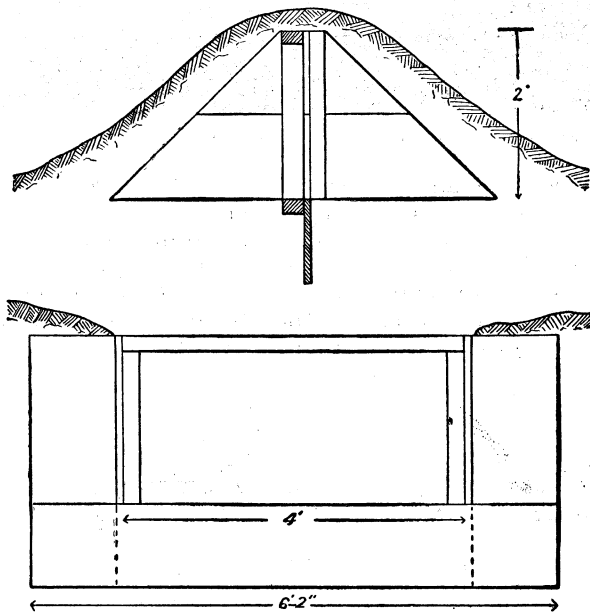


FIGURE 28.—Check box, showing section across embankment at top and lengthwise of bank at bottom

the first crop of alfalfa is ready to be cut. The dotted line in Figure 27 represents the general shape of the levee when first formed.

A ditch is built to carry water to each check or pair of checks. Its capacity should be fully equal to the quantity of water used, which in California is about 10 cubic feet per second. Each check should be provided with a box controlled by a gate of wood or concrete, similar to that shown in Figure 28.

In irrigating by the check method the entire flow of the ditch is turned into each check in turn. A large stream is used in order that it may quickly reach the portion farthest from the ditch. The water is allowed to run just long enough to reach the depth desired, after which it is turned into the next check.

BORDER IRRIGATION

The border method of irrigation consists essentially in applying water to a field which has been divided into a series of strips, lands, or beds, by low, flat levees usually extending in the direction of the steepest slope. A more complete discussion of this method is given in Farmers' Bulletin 1243, *The Border Method of Irrigation*.



FIGURE 29.—Preparing land with a Fresno scraper for border irrigation

Land being prepared for border irrigation is first plowed and then divided into a number of parallel strips which extend down the steepest slope. The width and length of these strips are determined by the nature of the soil, the quantity of water available, the slope of the land, and other factors. In sandy or gravelly soils that absorb water readily, their length should not exceed 330 feet and their width 25 feet. In ordinary loam soils, the usual dimensions are 30 to 40 feet wide and 400 to 600 feet long. In compact soils or in loam soils having compact subsoils the length may be increased to 1,000 feet and the width to 50 feet.

After the location of the various borders has been marked by a plow furrow, scrapers cross and recross the field at right angles to the borders, removing earth from the high places and depositing it on the borders.

The use of the Fresno scraper to prepare land for irrigation by the border method is shown in Figure 29. A modification of the

Fresno scraper mounted on wheels and operated from a seat attached to the axle is illustrated in Figure 30. This implement is made in several sizes, designed for 2, 3, or 4 horse teams or for tractor operation. Borders made with this implement are irregular, with steep slopes; but by being harrowed crosswise and lengthwise they can be made reasonably straight and rounding, so as to confine the water within each strip and at the same time permit the easy passage of mowers, reapers, and other implements. The space between borders should be made level and smooth. If it is not level the water will collect on the low side, and if the surface is not smooth the water will be retarded in its flow and distributed unevenly. A portion of a field prepared for irrigation by this method is shown in Figure 31.

The head ditch which furnishes water to each strip in turn or to two or more strips at the same time is located on a proper grade

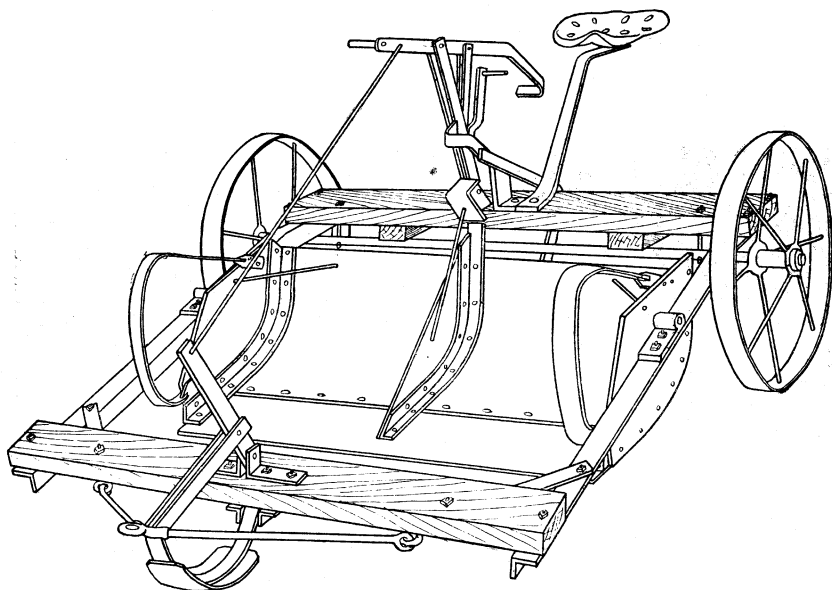


FIGURE 30.—An improved scraper extensively used in Idaho and other States

along the upper edge of the field. The water is checked in this ditch by a canvas dam or permanent structure, and one or more border gates are opened to admit water into the strips.

The temporary border opening protected by canvas is shown in Figure 32, the water being checked by a canvas dam. If the soil is sandy a large stream is used and the water is shut off as soon as it reaches the lower end of the strip. On tighter soils a smaller stream is used and may be allowed to run for a longer time. When this is done the water flowing off the lower end of the strip is caught in the next lower head ditch and redistributed to lower strips.

PREPARING LAND FOR GARDEN IRRIGATION

For obvious reasons the farm garden should be located as near to the farm buildings as possible. The next factors in importance in



FIGURE 31.—Field prepared for border irrigation

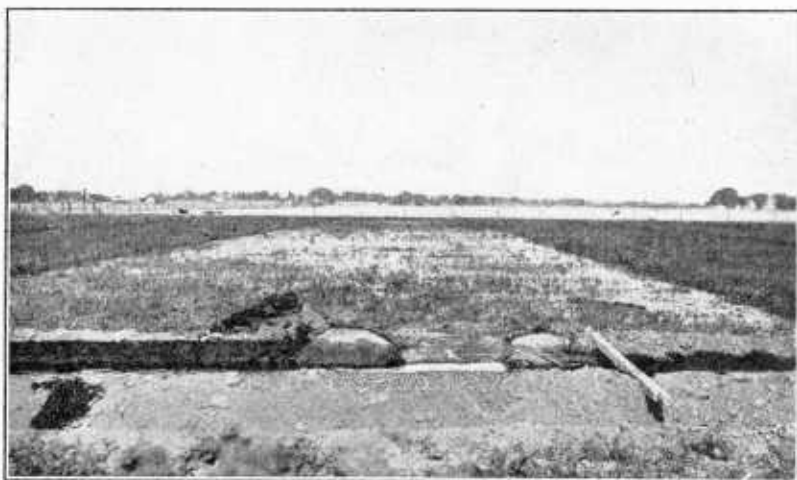


FIGURE 32.—Border opening with canvas protection and canvas drop

choosing its location are suitable soil and an ample water supply readily obtainable. A well-drained loam soil is the best for an irrigated garden. Soils which are naturally either too heavy or too light for gardening can be much improved by proper treatment. On adobe soils E. J. Wickson, former director of the California Agricultural Experiment Station, recommends the use of air-slaked lime, deep and thorough tillage, and the plowing in of as much coarse material as possible. He states:

Farmyard manure, straw, sand, old plaster, coal ashes, sawdust, almost anything coarse or gritty, which will break up the close adherence of the fine clay particles, release the surplus water, and let in the air, will produce a marked effect in reducing the hateful baking and cracking, root-tearing, and moisture-losing behavior of the adobe.

He recommends plenty of well composted and decayed manure for improving a light, sandy soil.

The water supply for the garden may be taken from a main supply ditch or from the source of domestic water supply. A near-by spring may sometimes be utilized by piping the water to a tank or reservoir and from thence to the garden. When water can not be carried by gravity, it is often drawn from wells by means of small pumps operated by electric motors, gasoline engines, or windmills. If the domestic supply is large enough to furnish 8 or 10 gallons per minute (500 or 600 gallons per hour) more than the quantity needed for household and livestock purposes, it will irrigate about an acre of lawn and garden. If a tank is available in which to store water during the night, the same supply will be sufficient for a somewhat larger area.

IRRIGATING DIFFERENT CROPS

ALFALFA

In the arid West alfalfa is the most important crop grown under irrigation. It was formerly most commonly irrigated by being flooded from field laterals but the border method is growing in favor. The check and corrugation methods are also used in some localities. In areas where the soil crusts badly a combination of the border and corrugation methods is used. The fields are prepared in the usual way for the border method, and after the alfalfa is seeded the strips are corrugated. The corrugations are used until the alfalfa is large enough to thoroughly shade the ground, after which the border method is used.

Alfalfa, like most other crops, should be planted in moist soil. It is almost impossible to get a satisfactory stand if the seed is planted in dry soil and moisture for germination supplied by irrigation. Better root development will be obtained by keeping the subsoil moist with occasional thorough irrigations instead of merely wetting the surface soil with frequent light applications. Maximum yields can be secured only by keeping the crop growing continuously. For this reason the water supply should not be cut off at haying time longer than necessary to permit the ground to dry sufficiently for the use of the haying equipment. The need for moisture is indicated by the color of the plant. In general, a dark bluish green, especially if dull looking, indicates a need for water; a yellowish

tinge often means that the soil is too wet, though with increasing lack of moisture it may follow the dark bluish green color.

For more complete information see Farmers' Bulletin 1630, Irrigation Practices in Growing Alfalfa.

GRAIN

Grainfields are irrigated usually by flooding from field laterals. Corrugations are used where the soil bakes after being flooded. For grain irrigation the border method is gaining in favor over the other methods. In the Mountain States most irrigated grain is raised in rotation with a leguminous crop, like alfalfa or clover. In some localities potatoes or beets form a part of the rotation. In rotating with cereals and legumes, or with cereals, legumes, and roots, the flooding and border methods are readily adapted to each kind of crop. This accounts, in part at least, for their general adoption in most irrigated districts.

For a more complete discussion of the irrigation of grain see Farmers' Bulletin 1556, Irrigation of Small Grain.

No fixed rule can be laid down for determining the proper time to irrigate grain. The soil should contain sufficient moisture at seed time to nourish the crop until it shades the ground. A quantity of water varying from 4 to 9 inches in depth, depending on the character of the soil, may then be applied. A second irrigation usually is applied when the grain is beginning to head out. At this time the plants are using the maximum amount of moisture, and as soon as there is a deficiency they begin to suffer. When the growth is checked at this stage, the lost vigor can not be wholly restored by subsequent watering and the yield is lessened. Newly seeded land suffers heavy losses of moisture by evaporation, but except for meeting this loss the water requirement of grain during the first six weeks of growth is small. The amount of water required during the last three weeks of growth is likewise small. After the last irrigation, the banks of the field laterals are leveled and the field is ready to harvest.

POTATOES

Potatoes and other root crops are irrigated through furrows made midway between the rows. These furrows should not be over 600 feet long, and less in light sandy soils with little fall. The furrows may readily be shortened by putting in more head ditches. Short furrows insure a more even distribution of water, and frequently prevent injury to the crop from water-logging of a part of the soil.

Unless the soil is well provided with moisture at seeding time, it should be irrigated before potatoes are planted. Potatoes can be "irrigated up" more successfully than other crops, but this is not good practice. The amount of moisture in the soil around the roots should be kept as nearly uniform as possible, except when the tubers are beginning to form; then it should be increased, since this is the critical stage in the life of the plant and more water is required. The moisture in the root zone should be carefully watched and irrigation water applied whenever the soil is getting dry. Since potatoes are not deep rooting and are sensitive to drought they require rather frequent irrigations after the tubers are set.

For more complete information on the irrigation of potatoes see Farmers' Bulletin 953, Potato Culture under Irrigation.

FRUIT TREES

According to E. J. Wickson formerly of the California Agricultural Experiment Station, apple trees should be planted on an average about 28 feet apart; cherry, plum, prune, apricot, peach, pear, and olive trees about 24 feet apart; and citrus trees 20 feet apart. In the Pacific Northwest, apple trees and pear trees other than Bartlett are commonly set 30 feet apart; apricot, peach, and Bartlett pear trees 20 feet apart; and sweet cherry trees 24 feet apart. On ordinary slopes, from 10 to 100 feet to the mile, the trees may be planted in rows down the steepest slope. Where the ground is so steep that water flowing in furrows will scour the bottom, the tree rows should extend diagonally across the slope so as to lessen the grade. On rolling ground the trees should be planted on contour lines so as to conform to the natural surface and make it easy to apply water. After the trees have once been planted there is no opportunity to change the slope of the land, and changes in direction of furrows are limited. For these reasons the land should be properly graded and the irrigation system carefully laid out before the orchard is set out.

The most common method of irrigating fruit trees in the western United States is by furrows from 300 to 1,200 feet long.

The length of the irrigation season varies from 1 to 12 months according to the rainfall, temperature, and crop. Young trees are watered by means of a furrow on each side of the row and, as the trees grow older and larger, the number of furrows is increased until all the space between the rows is watered. The purpose is to train the roots outward and downward so as to enlarge their feeding zone. Frequent borings or excavations should be made to find out not only the location of the roots but also how far and in which directions the water from the furrows has percolated.

For a more complete discussion of this subject see Farmers' Bulletin 1518, Orchard Irrigation.

PASTURES

The farmer on the irrigated lands of the Mountain States is far from the principal markets for his products. For this reason he must, so far as possible, sell concentrated products which can be shipped long distances economically. Dairy and other animal products come in this classification. Low cost production of animal products requires good pasture over a long season. In the semiarid sections, and also in some sections where irrigation is not generally practiced, irrigated pastures fill this need admirably.

Pastures may be irrigated by any of the flooding methods or by the corrugation method. The border method is probably the most generally satisfactory on the higher priced land. Most permanent pastures consist of a mixture of grasses including at least one legume. In some sections either ladino or sweetclover is used alone. Since most of these grasses are shallow rooted, only a small amount of water can be stored in the root zone of the soil between irrigations. Pastures, therefore, require frequent irrigation. In general, land in-

tended for pastures should be just as carefully prepared for irrigation as if intended for any other perennial crop. However, by using sufficient care in irrigation, land too steep and rocky for cultivated crops can be used successfully for irrigated pastures.

SMALL FRUITS AND VEGETABLES

In the arid and semiarid States it is, of course, as necessary to irrigate the small fruits and vegetables as any other crops. In other sections of the United States their irrigation is being extended from year to year.

These crops are nearly always irrigated by the furrow method. As most of them are shallow rooted and as the quality of the fruit often depends on quick, succulent growth, frequent irrigation is required. In some sections where the rotation system is used, a special schedule providing for irrigation at more frequent intervals is provided for the irrigation of gardens.

REDUCING WASTAGE OF WATER

The water which plants actually use is only a part of that which is diverted from streams for irrigation purposes. Large volumes are lost by seepage in the earth channels of canal systems. Similar losses occur in the ditches which supply farms, and a large part of the remainder is wasted in irrigating crops. The farmer is chiefly concerned in lessening the waste of water in his supply ditch and on his farm. Where water is scarce the supply ditch should be made more or less water-tight by lining it with cement concrete, cement plaster, asphalt, heavy crude oil, or clay puddle. Flumes or pipes may be substituted for earth ditches.

When the soil is irrigated by flooding, an uneven surface causes needless waste of water, extra labor in spreading it over the surface, and smaller yields. The water flows into the low places, which receive too much and may become water-logged, while the high places are left without water and the crop thereon is dwarfed. The land should be so evenly graded that water will flow in a thin sheet over the entire surface, and the excess water applied should be caught by the lower lateral.

Another common cause of waste is the lack of attendance. Water is often turned on a portion of a field and permitted to run without attention for hours and even days. On some farms the irrigators look after the water for 10 hours and turn it loose for the rest of the day. Under this practice the low places receive too much, the high places little or none, and a large part flows off the field to the injury of the roads and adjoining farms.

Too shallow and too frequent irrigation is another source of waste. Merely wetting the surface may result in the loss by evaporation of a large part of the water applied. For most plants, and particularly for all deep-rooted plants, the ground should be so prepared that water will readily percolate to a considerable depth beneath the surface, and enough water should be applied to moisten the subsoil. On the other hand, light, open soils retain but little moisture and should receive light, frequent irrigations. If heavy irrigations are

applied to such soils, a large part of the water will percolate below the reach of plant roots and may cause water-logging of low-lying land.

MAINTAINING THE PROPER PERCENTAGE OF SOIL MOISTURE

The main purpose of irrigation is to furnish the requisite amount of moisture to cropped soil. Either too little or too much moisture injures plants, and it is not easy to find out how much is best for a particular soil or crop. If soils were uniform in texture and were composed of the same materials, the proper quantity of water to apply would be much more easily determined, but there is an infinite variety in the texture and composition of soils. The soil on a single acre of ground may consist of several more or less distinct types. The problem is rendered still more complex by a wide variation in the moisture-holding capacities of soils. Clay soils may hold 40 per cent of their dry weight in moisture, whereas sandy soils may hold only 8 per cent. Coupled with this is a difference in the way in which the moisture is held in the soil. A certain percentage of soil moisture—which may be less than 2 per cent in sandy soils and as high as 18 per cent in clay soils—is held very tightly by the particles of soil and is not available, except to a very limited extent, to the rootlets of plants. Another portion is free to move and is drawn downward by the forces of gravity and capillarity.

That portion of the water which is neither drawn downward through the soil by gravity nor tightly held by the soil particles, is the portion available to the crop. So long as some of this available water is in all parts of the root zone crops will grow well. As soon as the available moisture in any considerable part of the feeding area is exhausted, the growth of crops will be retarded. It is then necessary to apply irrigation water if maximum yields are to be secured. Best results will be obtained if just enough water is applied to increase the moisture content of the whole root zone to the point at which water will begin to drain downward. It is, in fact, impossible to moisten all of the dry soil to any less degree than this. As the water moves downward it thoroughly moistens the soil as it goes. If the supply is insufficient to do this the moisture will not penetrate to the full depth of the dry layer.

The quantity of water to apply in one irrigation, the length of the interval between irrigations, and the total quantity used in any one season all depend on a large number of soil, crop, and climatic conditions. As already stated sandy soils retain little water and need to be watered frequently, but with relatively small quantities. The equivalent of a depth of 3 or 4 inches over the surface should be enough at any one time. Loam soils retain more water and may be watered at longer intervals but with larger quantities. In irrigating clay soils the chief difficulty lies in effecting a deep penetration of moisture. Special methods of application are often necessary to do this, but when once clay soils are well moistened throughout the root zone they retain the moisture a long time.

The quantity of water applied likewise depends on the kind of crop grown. Forage crops require the most water; a medium quantity is required for grain, potatoes, and fruit trees; corn, sorghum to

be cut for grain, and beans require the least water. The quantity needed also depends on the climate, particularly the rainfall.

Few farmers possess the technical skill and equipment to determine unaided the quantity of water required per acre and the best methods to employ in applying it, especially on land where water is being used for the first time. There are at least two points on which the water users should be informed. One of these is the minimum percentage of moisture in the soil at which plants wilt and fail to recover when water is added. The second is the effective water-holding capacity of the soil under crop. A knowledge of the first point enables the grower to apply water before the crop is injured permanently, and a knowledge of the second is a safeguard against the use of too much or too little water. Farmers needing such information should seek aid from the State agricultural college, either through the county agricultural agent and extension service or the experiment station, or from the United States Department of Agriculture.

DRAINAGE

Experience throughout the arid region has demonstrated that the greatest danger to irrigated lands is lack of drainage. Water lost from canals or applied to crops raises the ground water, which brings with it the salts dissolved from the soil. Capillarity brings this water to the surface, where it evaporates, leaving the salts to accumulate until all vegetation is destroyed. The only insurance against this is proper drainage. The drainage conditions are therefore equally important with the water supply and should be looked into with as much care. When there is not good natural drainage, artificial drainage must be supplied.

While good drainage is the only guaranty against harmful concentrations of salts, anything which will lessen the waste of water and thus check the rise of ground water will decrease the danger. The most effective means of accomplishing this object are (1) to prevent the larger losses due to seepage, in so far as funds will permit, by lining earthen channels, and (2) to more thoroughly prepare the surface of fields for irrigation, and apply the water in such a way that most of it will remain within the root zone of plants.

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